

REMARKS

This is in response to the Office Action dated July 10, 2006. In view of the foregoing amendments and following representations, reconsideration is respectfully requested.

In the previous Office Action, claims 1-4 are rejected under 35 U.S.C. 103(a) as being unpatentable over Pham et al. (U.S. Patent No. 6,051,125) in view of Ito et al. (JP 51-119703) and Chiaramonte (U.S. Patent No. 4,312,740) or Keller et al. (U.S. Patent No. 4,953,479) or Shaw (U.S. Patent No. 6,736,955).

The newly presented claim 1 recites the feature of supplying a reducing gas, composed mainly of hydrogen and carbon monoxide, produced by pyrolysis of an organic material to an anode side of an electrolyzer. As discussed in the specification on page 9, lines 2-5, because the reducing gas is mainly composed of hydrogen and carbon monoxide, there is no fear of electrode contamination caused by carbon deposition due to pyrolysis.

Thus, the reducing gas is produced via pyrolysis of an organic material. As a result, the hydrocarbon content is as small as several %. Therefore, even if the reducing gas is pyrolyzed in an electrolyzer, carbon is hardly deposited on the electrode. The reducing gas is obtained from an organic material, such as biomass, which generally contains a considerable amount of moisture. Accordingly, a reducing gas obtained from organic material usually contains a large amount of steam. This fact is advantageous from a viewpoint of preventing carbon deposition on the electrode.

On the other hand, the Pham reference discloses supplying a natural gas (i.e., methane) to the anode side. Clearly, the supply of methane would cause carbon deposition on the electrode. This carbon deposition results from pyrolysis of methane into carbon and hydrogen prior to reaction with oxygen on the electrode. Particularly, such pyrolysis occurs on an electrode catalyst made from, for example, Ni.

Attached is a sheet that includes Graph 1, which shows a change in temperature of free energy of formation "AG" of carbon deposition reaction from methane ($\text{CF1}_4 \rightarrow {}^4\text{C} + 2\text{H}_2$) and carbon deposition reaction from CO ($2\text{CO} \rightarrow {}^4\text{C} + \text{CO}_2$ or $\text{CO} + \text{H}_2 \rightarrow {}^4\text{C} + \text{H}_2\text{O}$). It can be seen from

Graph 1 that, while carbon deposition from methane easily occurs at temperatures of more than 550°C, carbon deposition from CO occurs at temperatures of less than 700°C.

Steam electrolysis is performed at a temperature of about 800 °C. At this temperature, carbon deposition from CO does not occur, while carbon deposition from methane does occur. Therefore, the use of a reducing gas, composed mainly of hydrogen and carbon monoxide (CO), can avoid carbon deposition problem.

As a method of preventing carbon deposition from methane, it has been customary to add steam to methane. The curved line in Graph 2, on the attached sheet, shows results of thermodynamic calculation of the amount of water (steam/CH₄) required for preventing carbon deposition. It can be seen from Graph 2 that steam/CH₄ is around 1 in every region. Particularly, in a temperature region between 700 and 500°C, carbon deposition is apt to occur, and it is thus required to increase steam/CH₄.

In the case of mixing methane and steam, a steam-reforming reaction occurs on the electrode. This steam-reforming reaction is an intense endothermic reaction, and thus results in a decrease in temperature. Such a decrease in temperature would cause an increase in overvoltage and a decrease in efficiency. Further, because the temperature approaches the above-mentioned region where carbon deposition is apt to occur, it becomes difficult to maintain a stable operation.

In contrast, according to the present invention, supplying of the above reducing gas causes a slight exothermal reaction. Accordingly, the temperature can be maintained, and a stable operation can be achieved. Further, use of the reducing gas can greatly lower an electrolytic voltage in the high-temperature steam electrolyzer as much as in the case of using methane. Therefore, use of the reducing gas is economically advantageous in view of it being produced from a low-cost organic material.

In view of the above, it is submitted that the present application is now clearly in condition for allowance. The Examiner therefore is requested to pass this case to issue.

In the event that the Examiner has any comments or suggestions of a nature necessary to place this case in condition for allowance, then the Examiner is requested to contact Applicant's undersigned attorney by telephone to promptly resolve any remaining matters.

Respectfully submitted,

Hiroyuki FUJIMURA et al.

By: _____



Michael S. Huppert
Registration No. 40,268
Attorney for Applicants

MSH/kjf
Washington, D.C. 20006-1021
Telephone (202) 721-8200
Facsimile (202) 721-8250
October 10, 2006